Virgin Islands Water Resources Research Institute Annual Technical Report FY 2015

Introduction

The United States Virgin Islands (USVI) is a Territory of the United States of America and consists of a group of several islands and cays located in the Lesser Antilles which separate the Atlantic Ocean and the Caribbean Sea. The USVI is about 1,200 miles southeast of Miami, Florida and 80 miles east of Puerto Rico. The principal islands in the USVI are St. Croix, St. Thomas, St. John and Water Island. Several of the other smaller islands in recent years have undergone various stages of development. In total, the islands have a combined area of approximately 137 square miles, are of volcanic origin and are mountainous. Tourism is the principal source of support for the economy.

With an annual rainfall of just over 40 inches, the USVI is one of the few places in the world where rain water harvesting is required by law. Buildings are constructed with cisterns that are sized and managed to provide a reliable and relatively safe water supply for users. Because of the hilly terrain, there are virtually no natural surface water supplies. Ground water is limited due to the geology and the risk of salt-water intrusion that could occur from coastal wells. The increasing potable water demands are met largely through use of desalination plants that provide water to the public water distribution systems. The islands experience challenges in collecting and disposing wastewater and water conservation and increasing efficiency in water-use are critical components of effective water resources management in the USVI.

The Virgin Islands Water Resources Research Institute (VI-WRRI) is hosted by the University of the Virgin Islands (UVI). UVI is the Territory's only institution of higher education and has campuses on the islands of St. Croix and St. Thomas and a research station on St. John. It is a Historically Black College or University (HBCU) and a land-grant institution. It was started in 1962. Though UVI is primarily an undergraduate institution, it offers graduate programs in teacher education, business administration, public administration, marine and environmental science and mathematics for secondary education teachers. The University's demographics reflect the local population in that it consists of a diversified mix of USVI residents and persons from the Caribbean region, the United States' mainland and other areas of the world.

The VI WRRI maximizes all resources available to it to serve the water resources research, information dissemination and training needs of the people of the U. S. Virgin Islands that might otherwise not be a priority in other settings. It works collaboratively with other units at UVI, with researchers in the U.S. Geological Survey's Islands Region and others, to address issues of local, regional, national, and international importance. Areas of focus in the past have included quantity and quality issues of water harvesting, development of alternative on-site sewage disposal systems and non-point source pollution in island environments. This year's projects investigated the use of rooftop surfaces as a means to improve the quality of harvested rainwater, examined the influence of land-based discharge on lagoonal water quality, developed educational material to increase U.S. Virgin Islands youth awareness of the importance of water and its conservation, and provided support for a joint conference held in Hawaii in December 2015 of the four island Water Resources Research Institutes (U.S. Virgin Islands, Puerto Rico, Hawaii, and Guam).

Research Program Introduction

The Virgin Islands Water Resources Research Institute at the University of the Virgin Islands supported two research projects in the FY2015 VI-WRRI program year. This year's projects investigated the use of rooftop surfaces as a means of improving the quality of harvested rainwater and examined the influence of land-based discharges on the water quality of a coastal lagoon. Of the two research projects, one was implemented on St. Croix and one with a collaborator at the University of Puerto in Mayaguez, Puerto Rico. Summaries of these projects follow.

Engineered Pervious Layer for Rooftop Rain Harvesting and Solar/Dark Inactivation of E. coli

Basic Information

Title:	Engineered Pervious Layer for Rooftop Rain Harvesting and Solar/Dark Inactivation of E. coli
Project Number:	2015VI251B
Start Date:	3/1/2015
End Date:	2/28/2016
Funding Source:	104B
Congressional District:	
Research Category:	Water Quality
Focus Category:	Water Quality, Water Use, Treatment
Descriptors:	None
Principal Investigators:	Sangchul Hwang, Henry H. Smith

Publications

1. Soto-Pérez L., S. Hwang, 2016, Mix design and pollution control potential of pervious concrete with non-compliant waste fly ash, Journal of Environmental Management, accepted for publication Mar 2016.
2. Soto-Pérez L., V. Lopez, S. Hwang, 2015, Response surface methodology to optimize the cement paste mix design: time-dependent contribution of fly ash and nano-iron oxide as admixtures, Materials & Design, 86, 22-29.
3. Jo M., L. Soto, M. Arocho, J. St John, S. Hwang, 2015, Optimum mix design of fly ash geopolymer paste and its use in pervious concrete for removal of fecal coliforms and phosphorus in water, Construction & Building Materials, 93, 1097-1104.

ENGINEERED PERVIOUS LAYER FOR ROOFTOP RAIN HARVESTING AND SOLAR/DARK INACTIVATION OF *E. COLI*

Problem and Research Objectives

Rain harvesting and reuse have been a principal source of potable water for the residents of the United States Virgin Islands (USVI). As rainfall is very seasonal, over 50% of the USVI residents rely on cistern rainwater. It should be noted that rainwater is not contaminant-free (Houston et al., 2012). Contamination can occur in rainwater before it is collected to the cisterns due to urban pollution, bird and reptile waste materials, roof material deterioration, and particulate matter deposition (Evans et al., 2006; Lee et al., 2012). Chemical and microbiological contamination have also been reported in cistern water (Al-Khatib and Arafat, 2009; Crabtree et al., 1996).

Engineered pervious layer (EPL) would benefit many communities that rely on rainwater as their potable water source (e.g., USVI). EPL has two-fold benefits. First, the pervious property of EPL serves as rainwater drainage with additional potential for the reduction of large particles and organic and inorganic contaminants (Luck et al, 2008; Mbabaso et al., 2013). Second, pathogens potentially present in rainwater will be removed and inactivated with the topical photocatalytic reactions of nano-titanium dioxide ($nTiO_2$) coated on the EPL in the presence of sunlight in daytime and the antimicrobial inactivation by nano-zinc oxide (nZnO) embedded in depth of the EPL in nighttime (Sanchez and Sobolev, 2010). In addition, rainwater retained in the meso- and micro- pores in EPL will reduce energy consumptions used for building cooling by the latent heat of moisture evaporation (Santamouris, 2010).

Methodology

The major components of EPL were nanomaterials ($nTiO_2$, nZnO, nano-iron oxide (nFe_3O_4)), gravels (4.75 - 9.5 mm), coal fly ash (FA) and ordinary Portland cement. In order to be pervious, EPL did contain fine aggregates (i.e., sand). $nTiO_2$ was the key component for the photocatalytic oxidative removal and inactivation of coliforms in sun-lit water, whereas nZnO was added to EPL to utilize their antimicrobial properties in the dark (Ge et al., 2012). Powder $nTiO_2$ (anatase, 18 nm) and nZnO (10-30 nm) were purchased from US nanomaterials (Houston, TX). Potential reductive contaminant removal was assessed with nFe_3O_4 that was composed of (in % vol.) nominal 10-nm magnetite (2.8-3.5), proprietary surfactant(s) (2.0-4.0), and water (92.5-95.2). nFe_3O_4 was purchased from Ferrotec (Bedford, NH). $nTiO_2$ was coated on the surface of the EPL after curing, whereas nZnO and nFe_3O_4 were integrally mixed in the EPL mixture. The BASF Glenium 3030 NS water-reducing admixture was supplied by a local company in Puerto Rico.

EPL specimens in triplicate were made in a 2^4 face centered, central composite design (Table 1). The four factors were the water-to-binder (W/B), fly ash-to-binder (FA/B), nFe_3O_4-to-binder (ENP/B) and water reducer-to-binder (WR/B) ratios. The binding material is the total of the powder materials (i.e., cement + FA).

The mixtures were prepared in a mechanical mixer and then transferred to cylindrical molds of 20.32 cm in length and 10.16 cm in diameter. Compaction of the specimens was made using a rod in accordance to ASTM C192. After 24 hours, specimens were demolded and cured for 28 days in lime-saturated tap water at ambient temperature (24±2 ^oC).

Table 1. Four factor Central Composite Design.

	Levels				
Factors	**Axial**	**Low**	**Center**	**High**	**Axial**
W/B	30	32	34	36	38
FA/B	0	10	20	30	40
ENP/B	0	1.7	3.4	5.1	6.8
WR/B	0	0.4	0.8	1.2	1.6

In accordance to ASTM C39, compressive strength was tested for the pervious concrete specimens after they were cured for 28 days in $Ca(OH)_2$-saturated tap water. Capping rubber pads (Gilson HM-370) were placed during the compressive strength test on the top and bottom sides of the specimens to provide a uniform load distribution by a 3000 kN Forney universal testing machine. The permeability of the samples was measured by quantifying the flow of water passing through the specimen, under a constant head difference. ASTM D2434 was modified to accommodate the experiment with EPL specimens.

For the assessment of *E. coli* and total coliform inactivation, two specimens were made with the optimum EPL mixture with an addition of 3% of nZnO. An acrylic mold with measurements of 30 cm in width x 30 cm in length x 5 cm in depth was used to cast the slab specimens. After demolding at 24 hours, the specimens were cured in lime saturated water for 28 days. $nTiO_2$ coating was applied to the optimum and control mixtures to determine coliform inactivation of the mixture with and without the coating.

Coliform-containing water was applied to EPL and the harvested water in the sun-lit or dark condition was tested for *E. coli* and total coliform concentration. EPL without nanoparticle addition was tested as a control under the same experimental conditions. The system was set up inside an environmental chamber equipped with a solar simulator and rainwater application unit (Figure 1). A solar simulator was used as the light source of the sunlight for the photo-catalytic inactivation of bacteria by $nTiO_2$. For the dark inactivation of bacteria by nZnO, the experiment was run without the light in the environmental chamber.

Figure 1. Environmental chamber equipped with rainfall and solar simulation.

E. coli and total coliforms were quantified by a membrane filtration technique with a 0.45 µm membrane filter. The filtered membrane was put in the petri dish containing m-ColiBlue24® from the HACH Company and then it was incubated at 35˚C for 24 hours. Blue colonies were reported as E. coli, while the sum of the blue and red colonies were reported as total coliforms.

Principal Findings and Significance

Optimized mix design: Numerical optimization of the independent variables for the EPL specimens was performed to identify the combination of variable settings that equally maximize the compressive strength while targeting the water permeability at 8 mm/s. Results showed that the combination of 34% W/B, 30% FA/B, 3% ENP/B and WR/B resulted in a permeability of 8.45 mm/s and a compressive strength of 13.8 MPa (Figure 2).

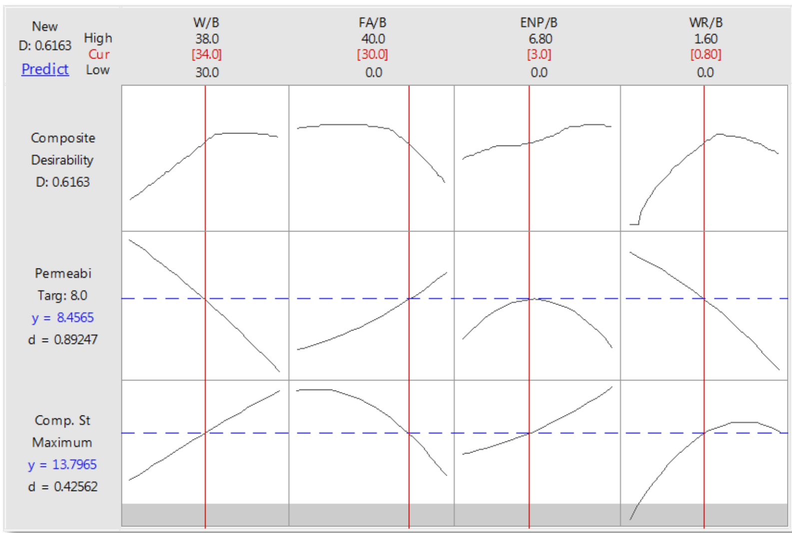

Figure 2. Optimization results of EPL specimens.

This optimum mixture composition and an addition of 3% of nZnO was used to make the EPL as shown in Table 2. The coating of $nTiO_2$ was done by mixing 50% of cement with 50% of the nanoparticles, with a W/B ratio of 95%.

Table 2. Mixture composition of EPL slabs.

Sample ID	W/B	FA	ENP (nFe_3O_4)	nZnO	WR	$nTiO_2$ Coating
S1A	34	30	3	3	0.8	Yes
S1B	34	30	3	3	0.8	No
C1A	34	0	0	0	0	Yes
C1B	34	0	0	0	0	No

Water quality: A very low inactivation of bacteria was achieved during most of the experiment due to the low contact time provided. After seven days of experiment, contact time was increased by closing the end corner of the slab and allowing water to exit by overflow over the slab. Figures 3a and 4a show that after the retention time increment, during the day time simulation both *E. coli* and total coliforms inactivation was slightly improved. No reliable relationship was observed between bacteria inactivation and surface coating of the EPL with the $nTiO_2$. Surface coating didn't work under this experimental condition probably due to the short contact time of the wastewater and the $nTiO_2$ coating as it only passed through the surface. Another reason might be that the approximate ~4,000 lux emitted by the light source was not strong enough to activate the photocatalytic activity of the $nTiO_2$, in comparison to the ~14,090 lux that can be obtained from direct sun light in a regular day in Puerto Rico. On the other hand, nZnO seems to be working as a night time bacteria inactivator, since specimens S1A and S1B achieved total coliform inactivation in the range of 25 to 45% along the experiment (Figure 3).

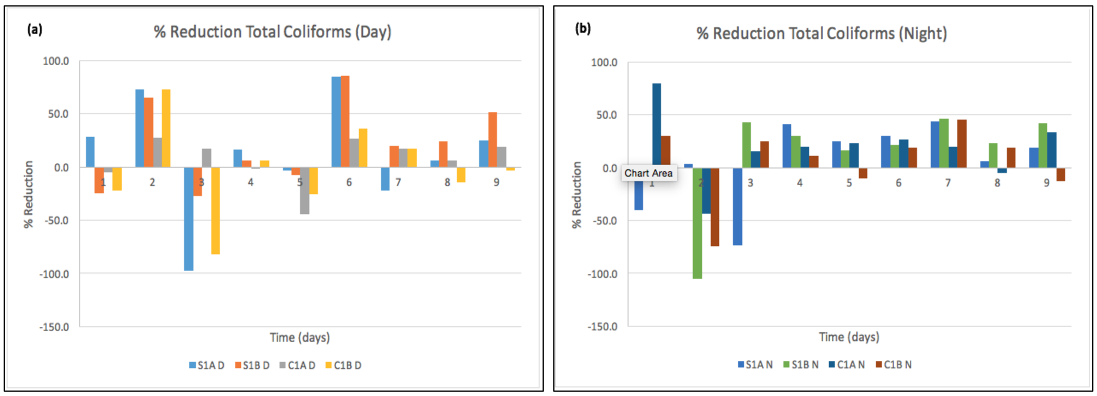

Figure 3. Total coliform reduction in water after treatment with the EPLs during (a) day and (b) night simulation.

It is important to notice that coliform inactivation was achieved better at higher water pH, as has been shown in previous experiments. Calcium hydroxide (CH) is one of the principal hydration products of concrete and is highly soluble in water, contributing to the high alkalinity of concrete (Mehta and Monteiro, 2014). After treating the wastewater with the EPLs, pH slightly increased. A notable decrease in the pH was observed as time passed, independent of the increase in contact time. The main reason for this behavior is that the CH was washed off the specimens, thus decreasing the pH of the resulting water as time passed. The water treated with the SIA and SIB specimens resulted in slightly higher pHs than the C1A and C1B specimens.

Conclusions

- Mix design with 34% W/B, 30% FA/B, 3% ENP/B and WR/B resulted in a permeability of 8.45 mm/s and a compressive strength of 13.8 MPa.
- The increment of W/B and WR/B resulted in a decrease of the permeability of the specimens due to drainage of the binder material and clogging of the bottom of the specimens.
- Compressive strength increased with the decrease of permeability due to pore structure reduction of the specimens.
- Surface coating of $nTiO_2$ didn't work as a photocatalyst for coliform inactivation.
- The incorporation of nZnO into the EPL had a positive effect as a coliform inactivator in night time.

Despite the potential of coliform inactivation with the incorporation of nZnO, the water infiltrated through the EPLs had alkaline pHs. Therefore, additional unit processing of pH neutralization is needed. However, it is recommended to assess the EPLs made of a different mixture containing a less alkaline but pozzolanic material, such as metakaoline, in order to eliminate the neutralization process. Use of light-weight aggregates is also recommended to facilitate placement of EPLs on the roof.

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Influences of Watersheds Inputs on Water Quality and Bioluminescent Dinoflagellates in Mangrove Lagoon, St. Croix, USVI

Basic Information

Title:	Influences of Watersheds Inputs on Water Quality and Bioluminescent Dinoflagellates in Mangrove Lagoon, St. Croix, USVI
Project Number:	2015VI252B
Start Date:	3/1/2015
End Date:	2/28/2016
Funding Source:	104B
Congressional District:	VI
Research Category:	Water Quality
Focus Category:	Nutrients, Sediments, Water Quality
Descriptors:	None
Principal Investigators:	Bernard Fernando Castillo, James Linehan Pinckney

Publication

1. Reale-Munroe, Kynoch, Bernard Castillo II and James Pinckney, 2016. Influences of Watersheds Inputs on Water Quality and Bioluminescent Dinoflagellates in Mangrove Lagoon, St. Croix, USVI in UVI Research Day 2016. St. Croix, VI.

INFLUENCES OF WATERSHED INPUTS ON WATER QUALITY AND BIOLUMINESCENT DINOFLAGELLATES IN MANGROVE LAGOON, ST. CROIX, USVI

Problem and Research Objectives

Bioluminescent bays and lagoons, which are often referred to as 'biobays' are rare and natural phenomena. Currently, reports suggest that there are approximately four to six year-round bioluminescent bays that remain worldwide (Seliger and McElroy 1968, Sastre et al. 2013, Zimberlin 2013). Depending on a myriad of natural and anthropogenic environmental factors (e.g., physical, chemical and ecological factors) bioluminescent bays increase and decrease in their ability to sustain high concentrations of the bioluminescent dinoflagellate, *Pyrodinium bahamense.*

Anthropogenic activities such as, dredging, channel disturbance, development and unwise management, threaten the few remaining bioluminescent water bodies in the Caribbean (Environmental Solutions, Ltd. 2005, Soler-Lopez & Santos 2010, Kenny et al. 2012, Sastre et al. 2013). In the U.S. Virgin Islands, land development, terrestrial erosion, sedimentation, urban runoff, leaking septic tanks, storm sewers, boat discharges, etc. collectively continue to degrade estuarine and nearshore coastal waters, including the waters surrounding Mangrove Lagoon in the Salt River National and Historical Park and Ecological Preserve, St. Croix, US Virgin Islands (VI DPNR 2004, Rothenburger et al. 2008, VI DPNR 2010).

This study takes place in the year-round bioluminescent, Mangrove Lagoon, which was first described by (Pinckney et al. 2014). The vibrant displays of light created by *Pyrodinium bahamense* when the water is agitated, make it a popular eco-tourism destination for locals and tourists alike. The research objectives of this project were to: (1) correlate potential watershed inputs with precipitation and changes in water quality (e.g., temperature, salinity, dissolved oxygen, turbidity, nutrients), (2) assess relationships between dinoflagellate and phytoplankton composition with changes in water quality parameters, and (3) map the temporal and spatial distribution of dinoflagellate and phytoplankton abundance in Mangrove Lagoon.

Methodology

Precipitation*:* A HOBO Data Logging Weather Station equipped with a HOBO® Pendant Event data logger was installed onsite. The data were used to determine 1-hr rainfall intensities, to calculate total rainfall during storm events and to summarize monthly rainfall data.

Water Quality Data – Temperature, Salinity, pH, Turbidity & Dissolved Oxygen: A YSI 6920 V2 multi-parameter water quality monitoring system (sonde) was used to collect turbidity, temperature, pH, dissolved oxygen, and salinity (derived from specific conductance) in Mangrove Lagoon. Discrete samples were obtained from the top (0.5 m) and bottom (2.0 m) of the water column using a YSI 650 MDS multi-parameter display in tandem with the sonde. Relative baseline data were established with bi-weekly sampling intervals at 4 fixed locations in Mangrove Lagoon. Sampling intervals were increased to approximately every 2 – 3 days for 7 – 10 days following intense precipitation events suspected to generate runoff into Salt River Bay and Mangrove Lagoon. Precipitation was graphically plotted with water quality parameters and analyzed using scatter matrices and Pearson's correlation statistics to investigate potential relationships between precipitation and water quality variables.

Water Quality Data – Orthophosphate, Nitrite/Nitrate & Ammonium: Water samples for orthophosphate, nitrate/nitrite and ammonium were collected simultaneously during the discrete sampling events with the sonde, i.e., bi-weekly with increased sampling intervals following intense precipitation events. Water samples were collected using a 1 m integrated water column sampler (surface waters) and a horizontal Niskin bottle (0.5 m from the bottom) from the 4 fixed locations within Mangrove Lagoon. For determining nutrient concentrations, water filtrate (0.7 µm filtered) was analyzed for orthophosphate, dissolved inorganic nitrogen as nitrite/nitrate, and ammonium using a Lachat Quick-Chem 8000 nutrient auto-analyzer according to standard methodology (Johnson & Petty 1983, Zimmerman & Keefe 1991, Grasshoff 1999). The samples were analyzed for dissolved nutrient concentrations and phytoplankton community composition/biomass.

Phytoplankton Data – Dinoflagellates, Diatoms & Cyanobacteria: Water for phytoplankton analyses was filtered through glass fiber filters (Whatman GF/F) using a gentle vacuum. Phytoplankton photopigment concentrations were measured using high performance liquid chromatography (HPLC; Pinckney et al. 2001). Filters were lyophilized for 18-24 hours at -50 °C then extracted by adding 750 µl of 90% aqueous acetone solvent followed by storage in the dark for 12-20 hours at - 20°C. Filtered extracts (250 µl) were injected into a Shimadzu HPLC with a single monomeric column (Rainin Microsorb, 0.46 × 1.5 cm, 3 µm packing) and a polymeric (Vydac 201TP54, 0.46 × 25 cm, 5 µm packing) reverse-phase C18 column in series. A non-linear binary gradient consisting of solvent A (80% methanol: 20% 0.5 M ammonium acetate) and solvent B (80% methanol: 20% acetone) was used for the mobile phase (Pinckney et al. 1996). Absorption spectra and chromatograms (440 ± 4 nm) were obtained using a Shimadzu SPD-M10av photodiode array detector and pigment peaks were identified by comparing retention times and absorption spectra with pure standards (DHI, Denmark). The synthetic carotenoid β-apo-8'-carotenal (Sigma) was used as an internal standard. Pigment concentrations were further analyzed using ChemTax (v. 1.95) to determine the relative abundance of major phytoplankton groups (Pinckney et al. 2001, Higgins et al. 2011). ChemTax calculates the relative concentration of different algal groups in units of chl *a*. Thus total chl *a* is partitioned into the contribution of individual algal groups. The initial pigment ratio matrix used for this analysis was derived from Mackey et al. (1996). The convergence procedure outlined by Latasa (2007) was used to minimize errors in algal group biomass due to inaccurate pigment ratio seed values. The major phytoplankton groups used for ChemTax categories were based on qualitative microscopic examinations of water from the bioassays.

Principal Findings and Significance

On the island of St. Croix, 2015 ended as the 3rd driest (during the dry season) and 6th wettest (during the wet season) year on record (Martínez-Sánchez 2015). On April 1, 2015 the U. S. Department of Agriculture (USDA) designated St. Croix as a Primary Natural Disaster Area due to drought (USDA, 2015). Water temperatures in Mangrove Lagoon ranged from 26.3°C on December 23, 2015 to 31.3 °C on June 8, 2015 (Fig 1). The average water temperature was 29.3 °C (± 1.41 SD, n = 231). Temperature decreases were often evident following large precipitation events, however no significant correlations were determined ($p > 0.01$). The average salinity was 38.7 practical salinity units (psu; ± 2.17 SD, n = 231). Salinity ranged from 43.5 psu on July 9, 2015 to 35.2 psu on September 9, 2015. The highest salinity (43.5 psu) was during the 2nd driest month on record (Martínez-Sánchez 2015). The lowest salinity (35.2 psu) corresponded to 15 days after the highest rainfall event of the study period, Tropical Storm (TS) Erika on August 27, 2015. Salinity and 12-day cumulative precipitation were negatively correlated ($r = -0.68$, $df = 28$, $p < 0.01$). The pH values were highest on January 6, 2016 (7.72) and lowest on October 19, 2015 (7.37). The average pH was 7.53 (± 0.10 SD, n = 231). The average turbidity was 5.48 nephelometric turbidity units, NTU (± 3.18, n = 223). Turbidity ranged from 10.19 NTU on June 25, 2015 to 0.000 NTU on December 2, 2015. Turbidity data were not found to be significantly correlated with precipitation events ($p > 0.01$). Dissolved oxygen ranged from 6.20 mg/L on December 23, 2015 to 4.12 mg/L on January 17, 2016. The average DO was 5.01 mg/L (± 0.56 SD, n = 231). There was not a significant correlation between precipitation and DO. No direct correlations were found between precipitation and the five water quality parameters tested, except between precipitation and salinity.

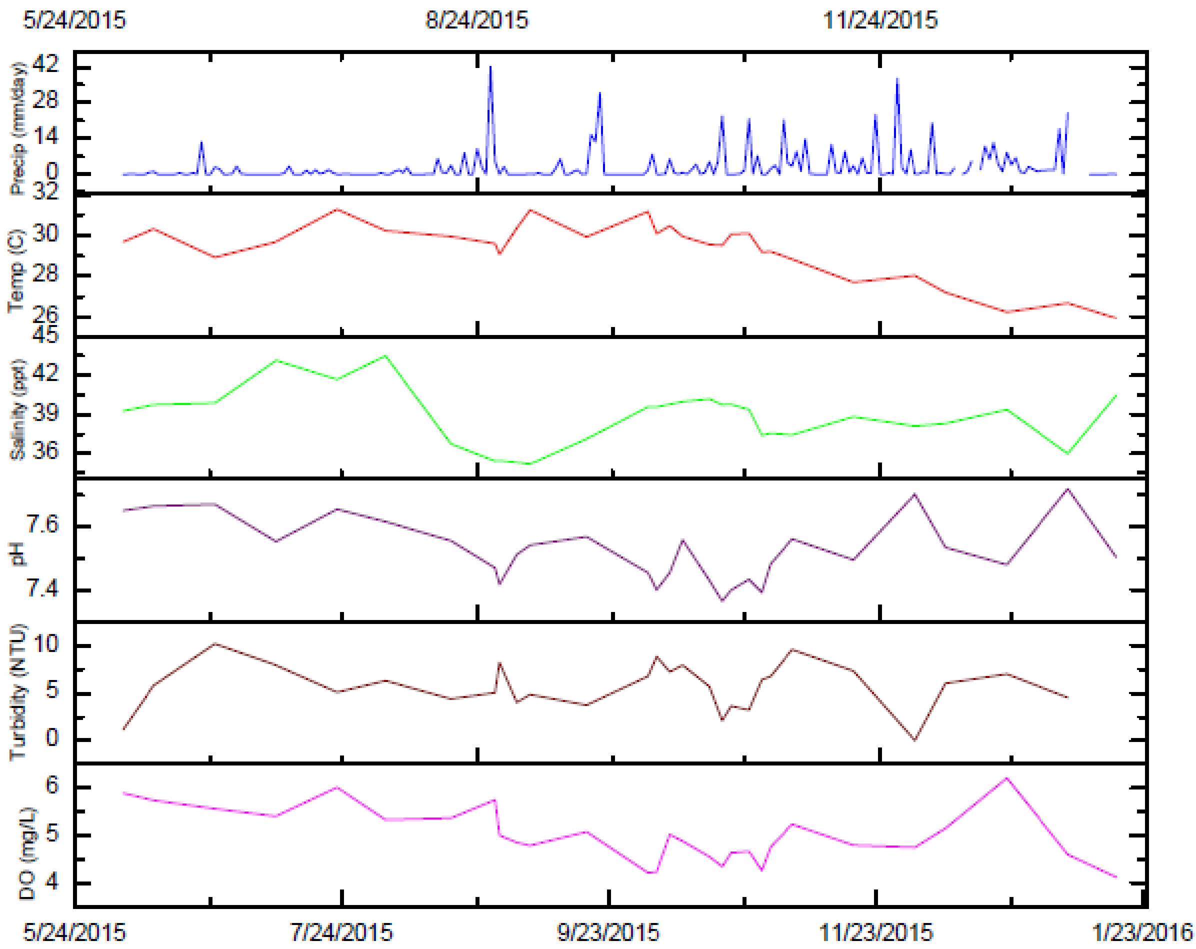

Figure 1. Graphical data of daily precipitation, water temperature, salinity, pH, turbidity and dissolved oxygen over the study period.

Analysis of the spatiotemporal data for phytoplankton abundances suggest a series of small phytoplankton "blooms" occurred in July, October, December, and January. Chl *a* concentrations were significantly higher in the bottom waters compared to surface waters. Diatoms, cyanobacteria, and dinoflagellates were the primary groups responsible for the blooms, with a larger contribution of dinoflagellates in the fall period. There were two diatom blooms, one in July and the other in late December. Dinoflagellates exhibited 3 distinct concentration peaks (i.e., "blooms") in October, December, and January. Like total chl *a*, dinoflagellate concentrations were higher in the bottom waters relative to surface waters. Cyanobacteria concentrations were higher during June-July and October. Concentrations of all algal groups except cyanobacteria were higher in the late fall and early winter months (November - January). Although the blooms were widely dispersed, the persistence of the blooms appeared higher at station 3, near the center of the lagoon.

Plots for the pooled data (all stations, surface and bottom) for the three most abundant phytoplankton groups for each sampling date illustrate the bloom periods as well as a large increase in the variability of concentrations in the fall period (Fig. 2). The relationship between daily rainfall and the concentrations of the total phytoplankton community and dinoflagellates was examined by overlaying the data from the weekly sampling (Fig. 3). There was no obvious direct correlation between rainfall and concentrations of total phytoplankton or dinoflagellates.

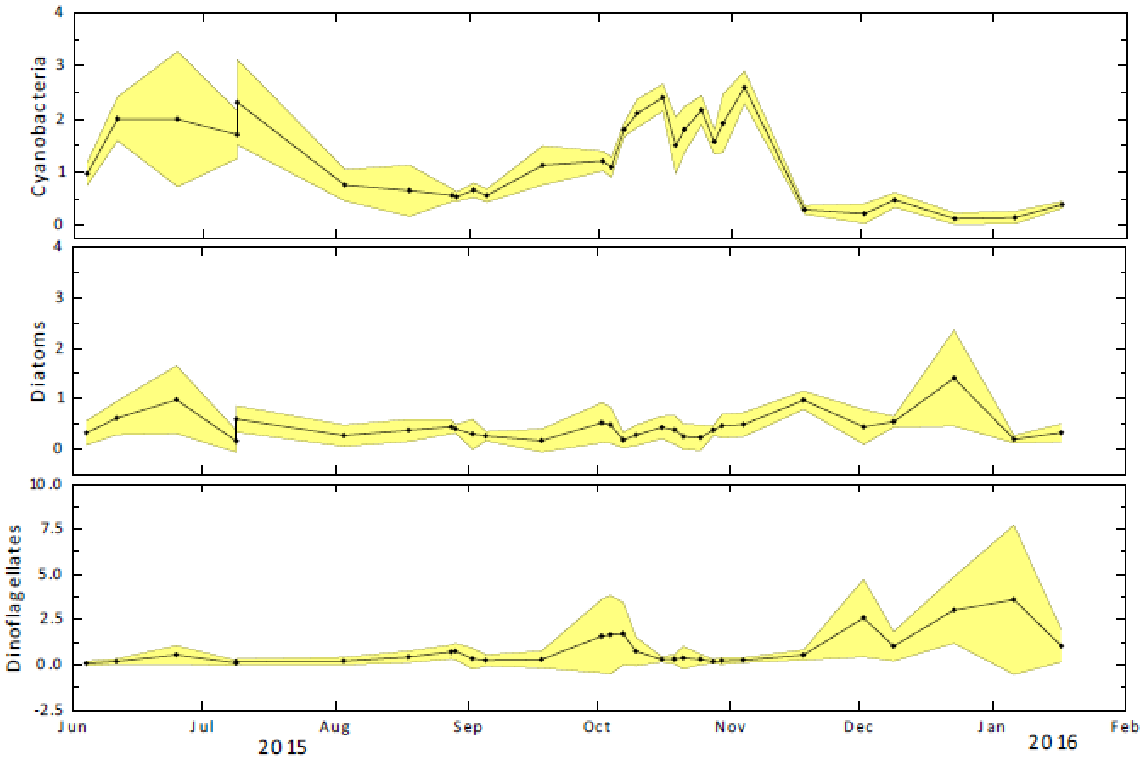

Figure 2. Mean concentrations (in µg chl *a* l^{-1}) of dinoflagellates, diatoms, and cyanobacteria. Yellow shading indicates ± 1 sd.

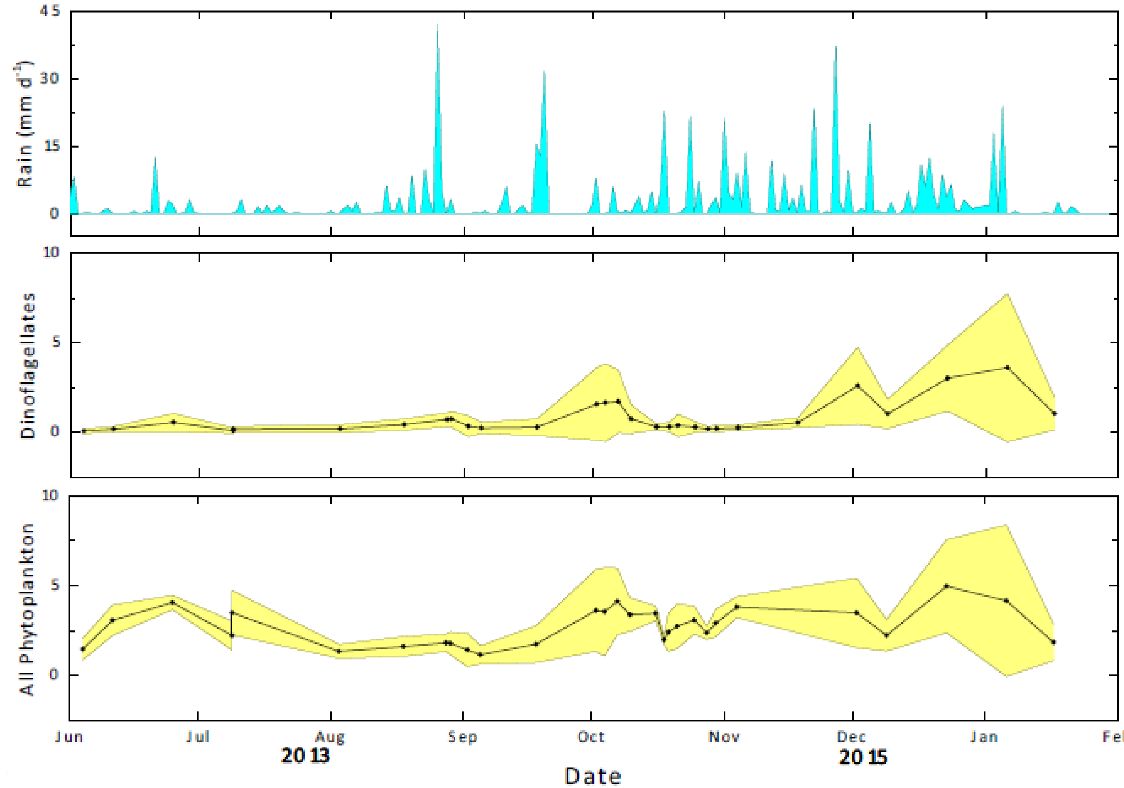

Figure 3. Mean concentrations (in μg chl *a* l^{-1}) of all phytoplankton and dinoflagellates compared with daily rainfall. Yellow shading indicates ± 1 sd.

Conclusions

The bioluminescence in Mangrove Lagoon is part of a unique and rare ecosystem found in the Salt River Bay National and Historical Park and Ecological Preserve on the central, northern coast of St. Croix, US Virgin Islands. Existing anthropogenic activities in the Salt River watershed and planned construction projects on the shores of Mangrove Lagoon will likely affect the existing physical, chemical and biological conditions in Mangrove Lagoon. The primary objectives of this study were to determine potential correlations between storm events, water quality and phytoplankton composition. No direct correlations were found between precipitation and changes in water quality, except between 12- day cumulative precipitation and salinity ($r =- 0.68$, $df = 28$, $p < 0.01$). Similarly, no direct correlation was found between changes in water quality parameters and phytoplankton groups.

The phytoplankton community in Mangrove Lagoon is composed primarily of diatoms, dinoflagellates, and cyanobacteria. The relative contributions of each of these groups seem to vary seasonally. Changes in phytoplankton biomass and community composition were not directly related to DIN concentrations or N:P ratios. During the day, phytoplankton concentrations were higher in the bottom waters, possibly due to negative phototaxis in the shallow lagoon waters. Phytoplankton concentrations were low and relatively constant, with dinoflagellates composing as much as 90% of total phytoplankton biomass. In general, most rainfall events do not result in increased nutrient concentrations. However, it is possible that nutrient uptake occurred at time scales shorter than our weekly sample collections.

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Information Transfer Program Introduction

Two VI-WRRI projects were supported through the Information Transfer Program during the 2015-2016 program year: the Water Ambassador Program and the Second Conference on Water Resource Sustainability Issues on Tropical Islands. Support from 104b funding resulted in educational material and programming that increased awareness of the importance of water and its conservation among USVI elementary and middle school students and a successful joint conference in Hawaii in December 2015 of the four island Water Resources Research Institutes (U.S. Virgin Islands, Puerto Rico, Hawaii, and Guam). Important to note, however, is that all projects conducted through the VI-WRRI are required to include elements of information dissemination and training in their activities. This was done and is evident through the public presentations that were made and the many students, both graduate and undergraduate, that participated in the research projects.

Water Ambassador Program

Basic Information

Title:	Water Ambassador Program
Project Number:	2015VI250B
Start Date:	3/1/2015
End Date:	2/28/2016
Funding Source:	104B
Congressional District:	
Research Category:	Social Sciences
Focus Category:	Education, Hydrology, Water Supply
Descriptors:	None
Principal Investigators:	christina marie chanes, David C Morris, Avram Gerald Primack

Publications

There are no publications.

WATER AMBASSADOR PROGRAM: A PILOT PROGRAM OF EDUCATION ON THE HYDROLOGIC CYCLE AND WATERSHED ISSUES TARGETED AT STUDENTS IN PUBLIC AND PRIVATE SCHOOLS IN THE UNITED STATES VIRGIN ISLANDS

Problem and Research Objectives

The United States Virgin Islands is a small territory just to the east of Puerto Rico that consists of three main islands, St. Thomas, St. Croix, and St. John, and a few smaller, mostly unpopulated islands. The majority of the people in the Territory live on St. Croix and St. Thomas. St. John and Water Island have fewer people. In addition to permanent residents, St. Thomas is one of the busiest tourism destinations in the Caribbean (Allen 1992) with more than 2 million visitors annually in recent years (USVI BER 2012). A significant proportion of the population of these islands draws their water from cisterns that collect rooftop water. The rest are dependent on groundwater sources. Everyone must purchase water purified in reverse osmosis when there are no other sources. Because of the small size of the islands, surface water supplies are limited and the availability of groundwater supplies is restricted by high relief and small aquifers. Most residents away from major towns rely on gathering rainwater from their personal rooftop into cisterns that they maintain themselves. Streams only flow for short periods after rainfall, are nearly dry for the rest of the year, and are heavily impacted by roads and erosion from poor construction practices high in their watersheds. All of these forces place great stress on natural hydrologic systems throughout the Territory and on St Thomas in particular.

There is a great need for education about water resources and their management on St. Thomas. There is also need for data collection on the status of streams and watersheds and increased understanding of climate patterns on the island. This proposal started and implemented a model educational program that introduced sixth grade students to good water and landscape conservation practices, created a system for collecting crowd source data (data collected by the public through a web mapping interface) on the status of hydrologic systems in the Territory using these students to report on their own watersheds, and increased the spread of the weather station system currently operated by the University of the Virgin Islands (UVI) on St. Thomas by bringing a station to each participating school.

Methodology

In response to the need for education in the public and private schools the Water Ambassador Program was created by Ms. Chanes in Cooperative Extension Service as part of the 4H program at UVI. The goals of the in-school program were to: (1) create awareness of and to reduce nonpoint source pollution, (2) bring attention to the importance of water quality and the need for water testing in schools, homes and the community, and (3) encourage and promote understanding of watersheds. These were accomplished through the development of a model educational program, the installation of weather stations at each participating school, and the creation of online, web-mapping applications that allowed students to report observations about their landscape and to see the watershed observations made by others.

Principal Findings and Significance

More than 350 students from seven schools participated in the Water Ambassador Program (Table 1). These include youths from ESL classes who spoke multiple languages in 4th through 6th grade and local students from 6th through 12th grades. Six weather stations were installed at these schools, significantly adding to the existing weather station network on St. Thomas (Table 2). Students were introduced to the weather station and how it reports data. More than 16 teachers and six administrators participated in the program and gained access to the weather station on the school grounds (Table 1). Many more teachers and schools requested to participate in the program than could be accommodated.

Table 1. Over 350 students, six teachers and six administrators participated.

School	Teachers/ Administrators	Students
Addelita Cancryn Junior High School	4/2	150
E. Oliver Benjamin Elementary School	3/1	100
CAHS*no station due to proximity to Lockhart Elementary School	3/0	20
Ivanna Eudora Kean High School	1/0	20
VI Montessori School International Academy	1/0	10
All Saints School	1/1	Participates in year 2
Lockhart Elementary School	3/2	98

Table 2. Six schools received weather stations as part of the program.

School	Grades
Addelita Cancryn Junior High School	7-8th
E. Oliver Benjamin Elementary School	K-5th (4-5)
Ivanna Eudora Kean High School	9-12th
VI Montessori School Int’l Academy	K-12 (private)
All Saints School	K-12 (private)
Lockhart Elementary School	K-6 (4-6) (ESL)

Web mapping application pages were created that are available on the Citizen Science tab of the GeoCAS web page (geocas.org). Because the Department of Education firewall system would not let outside web pages into the schools we were not able to use them in the classroom with students. We are working on this and expect to get them into the schools in the next school year where they will become part of the in-class program. These pages were used from home and during the Big Production at the end of the project where students took part in a daylong, hands-on learning activity at UVI.

Each weather station and its associated online reporting page are available to the public through the GeoCAS website to the general public (geocas.org). An example of weather station output from a station currently operating in this network can be found at http://www.weatherlink.com/user/uviwsx6/. The watershed model purchased as part of the project is also being used in public events around the Territory. In February of this year, Dr

Primack and Ms. Chanes travelled to St Croix with the watershed model and shared it at the annual Virgin Islands Agriculture and Food Fair.

The final Big Production included 80 students and teachers from two schools. These students met with faculty and administrators at UVI, where they presented the results of their own investigations into water quality topics and heard presentations from faculty and administrators at UVI about the college experience. We took advantage of the Virgin Islands Experimental Program to Stimulate Competitive Research's Celebrity Scientist Program to introduce students to Engineer and 3D printmaker Arthur Spivey, who is from the U.S. Virgin Islands, to demonstrate 3D printing. Our invited speaker, Dr. Walter Silva of the University of Puerto Rico at Mayaguez observed the student presentations and spoke with students during the event. His final presentation drew together the threads of the student presentations into his own presentation on the water cycle, how we are tied to it, and how we need to care for it.

The Water Ambassador Program introduced students to public action by having each school create and record a public service announcement that has been aired on WUVI, UVI's radio station. They also created short video presentations. Because Ms. Chanes, PI of the project, has extensive experience working with radio and has a regular weekend show, students in the program were able to prepare their own short radio spots which they recorded during a visit to the radio station this along with several interviews on a variety of shows at WUVI, which continue to be played regularly on WUVI and are archived on the WUVI SoundCloud which hosts podcasts.

Student Water Ambassadors also learned how to present water-related materials to their peers, both on- and off-island. This year's Water Ambassador Program graduates of both Lockhart Elementary School and E. Benjamin Oliver Elementary School presented their efforts in a school assembly. The Water Ambassador Program was presented by five high school aged youth in August 2015 at the 31st Annual West Indies Agricultural Economics Conference held on St Croix to more than 60 researchers and farmers from across the nation and 13 countries.

An unexpected benefit of the Water Ambassador Program is that it has also connected others at the University and in the Territory, including UVI's Etelman Observatory and the Virgin Islands Department of Agriculture. Dr. Primack is currently in discussions with Dr. Silva, our guest presenter at the Big Production that have led to several proposals in the area of Food, Energy, and Water.

Conclusions

The Water Ambassador Program advanced science literacy in schools on St. Thomas. The program involved more than 240 classroom contact hours in the area of water resources covering water conservation, water resources, and their management on islands, with more than 16 teachers, six administrators and 350 students. Youth collected data on the status of watersheds, thereby increasing their understanding of climate change and climate patterns.

The Big Production gave youth a chance to present their findings in a formal college level setting and afforded them the chance to interact directly with a variety of researchers. In the future, more administrators and teachers should be trained. Lessons included writing, vocabulary and spelling exercises including the Water Droplet essay which drove home the message that water conservation and hydrology affect them, and water resources must be conserved not only here but all over the world. In addition, the youth were able to apply the water resources lessons to agriculture, fisheries, and other food sources.

Water chemistry testing should be included in future programs as the youth enjoy taking part in it and it served as an introduction to chemistry. Youth also asked about the physics of water and sediment movement down slopes during storm periods, which could damage homes and beaches.

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Second Conference on Water Resource Sustainability Issues on Tropical Islands

Basic Information

Title:	Second Conference on Water Resource Sustainability Issues on Tropical Islands
Project Number:	2015VI253B
Start Date:	3/1/2015
End Date:	2/28/2016
Funding Source:	104B
Congressional District:	Not Applicable
Research Category:	Not Applicable
Focus Category:	Water Supply, Management and Planning, Climatological Processes
Descriptors:	None
Principal Investigators:	Henry H. Smith

Publications

There are no publications.

December 1-3 2015, the VI WRRI participated in the Second Conference on Water Resource Sustainability Issues on Tropical Islands held in Honolulu, HI. Per reporting instructions received from the USGS for this joint conference, the full report revealing conference details is available through the Hawaii Water Resources Research Center’s FY 2015 Annual Report.

USGS Summer Intern Program

None.

Student Support					
Category	**Section 104 Base Grant**	**Section 104 NCGP Award**	**NIWR-USGS Internship**	**Supplemental Awards**	**Total**
Undergraduate	6	0	0	0	6
Masters	2	0	0	0	2
Ph.D.	0	0	0	0	0
Post-Doc.	0	0	0	0	0
Total	8	0	0	0	8

Notable Awards and Achievements